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# Information Integration: Challenges and Reponses

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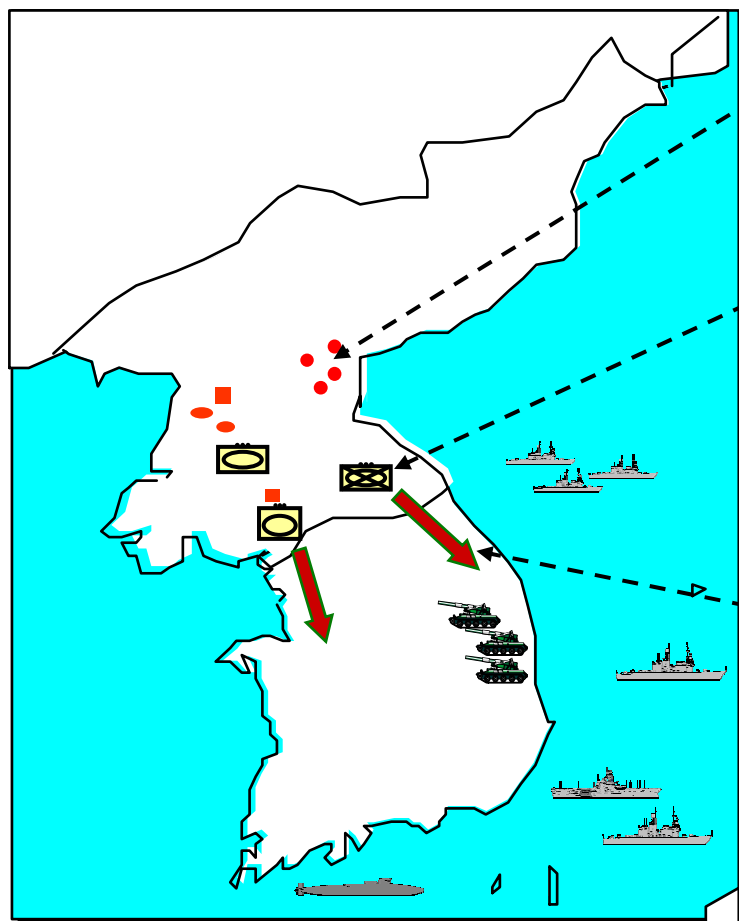


# Global War on Terrorism (GWOT) / Maritime Domain Awareness (MDA)



- The enemies of yesterday were predictable, homogeneous, rigid, hierarchical, and resistant to change
- ***Today's enemies are dynamic, unpredictable, diverse, fluid, networked and constantly evolving leading to complex problem sets***
- In the context of GWOT, MDA takes on a strategic dimension and must:
  - Collect, fuse, and disseminate enormous quantities of data drawn from U.S. joint forces, U.S. government agencies, international coalition partners and forces, and commercial entities
  - Complexity is compounded by:
    - Threats have no formal doctrine
    - Fewer analysts are available to work more data and more problems
    - Required reaction times have decreased from days to minutes

The *first step* is to achieve **increased awareness** of activities in the maritime domain -- followed by **situation understanding** and **threat intent**



**Level 0/1 Data Fusion — Object Refinement:**

spatial-temporal registration; observation-report-track association, continuous state estimation (e.g. kinematics) and discrete state estimation (e.g. ID, type, attributes)

**Level 2 Data Fusion — Situation Understanding:**

object clustering and relational analysis, interpretation of relationships among objects and events in the context of the operational environment (e.g. force structure, membership, behaviors, dependencies, communications, physical context)

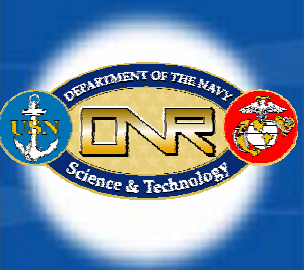
**Level 3 Data Fusion — Threat Assessment:**

threat intent estimation, event prediction, own force vulnerability, and consequence prediction

**Level 4 Data Fusion — Process Refinement:**

adaptive data acquisition and processing to support mission objectives (couples to resource management)

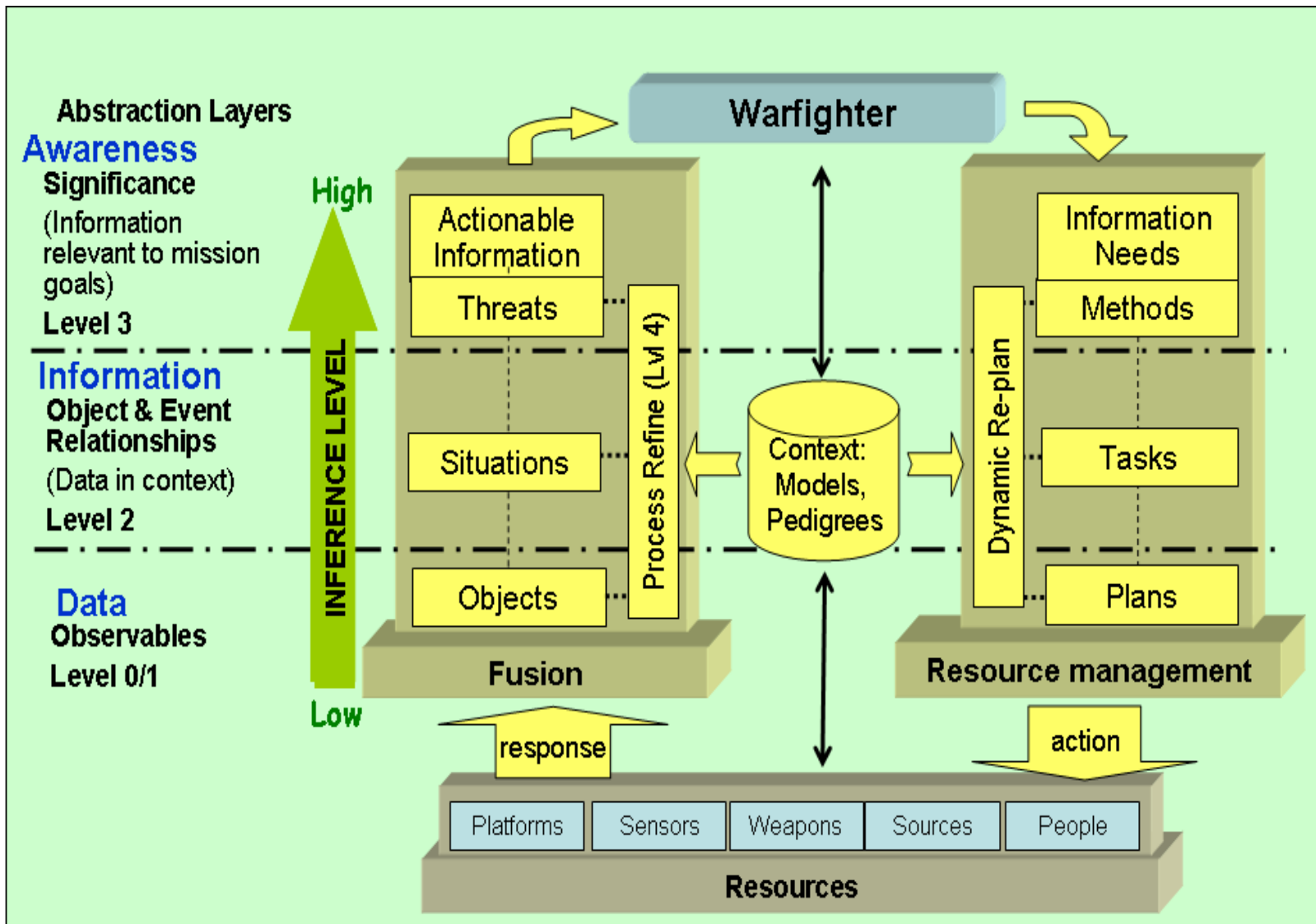
From: JDL, Data Fusion Group, Data Fusion Model

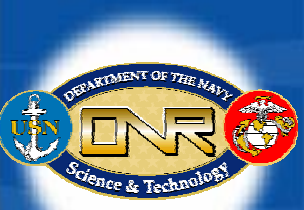


# Warfighting Requirements



- Future operational environments - *Global War on Terrorism (GWOT) and Maritime Domain Awareness (MDA)* – require technologies to support information needs:
  - Regardless of location
  - Consistent with the user's level of command or responsibility and operational situation
- FORCEnet will achieve this in part by relying on
  - Discovery and Invention (D&I) projects
  - Enabling Capability products
  - ACTDs





# Technical Challenges



- Multi-INT multi-sensor level 1 data fusion coupled to automated sensor management
  - Manage information overload and massive data from multiple disparate sources
    - Out of sequence measurements / reporting
    - Sensor data with varying representations of the same object
  - Object level refinement, locations, tracks, IDs, and features
  - Consistent representation in data or picture layer across the enterprise
- Level 2/3 data fusion algorithms
  - Representation of actionable information responsive to situation and threats
  - Techniques for inferencing uncertainty
  - Knowledge bases and knowledge representation to capture warfighter expertise
  - Management of large number of hypotheses with human supervision
- Net-centric enabled / Service Oriented Architecture (SOA) Compatible
  - Reliable data & information access with drill down support
  - Metadata and pedigree for context, common models for consistency
  - User relevant metrics and information detail



## Current Efforts



- **Ongoing D&I projects**
- **Supporting two new Enabling Capabilities**
  - EC1C: Combat ID Information Management of Coordinated Electronic Surveillance
  - EC1D: Combat ID in the Maritime Domain to Reveal Contact Intent
- **Proposed ACTD: Timely Maritime Information and Exchange (TiMIX)**



## Information Integration D&I Program Focus



- Program examines critical S&T needs of
  - Automatic association and merger of information for unified presentation
  - Automated recognition and cueing for significant patterns of information, computer-aided reasoning for task-oriented information dissemination
  - Timely, accurate information and sensor fusion from heterogeneous sources





## Specific Program Goals



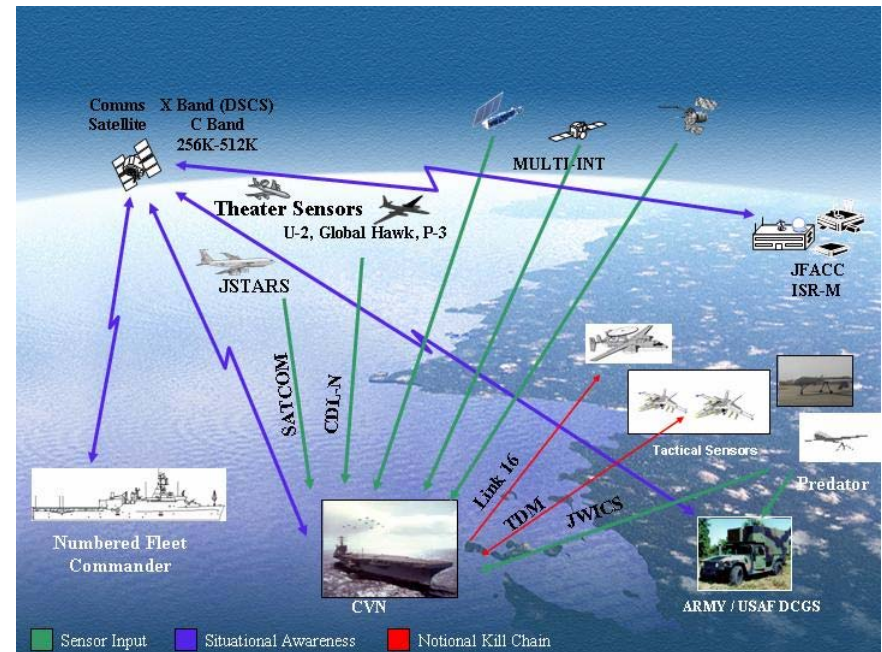
- Automated image understanding
  - Issues to Address
    - 40% of imagery collected not screened due to availability of analysts
  - Candidate projects
    - Automatic target recognition (ATR) algorithms with current/evolving imagery exploitation standards
    - ATR algorithms that can operate under dynamic constraints

## Products/ Deliverables

- New representations of Level 1 data to support the distributed fusion of disparate sources of information
- New data schemas and methods to allow more efficient assembly of a Single Integrated Picture using images, track data, intelligence and incomplete track data
- Sensor management algorithms to optimally manage bandwidth & sensor cuing

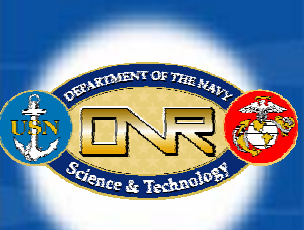
## Naval Relevance

- Maintain Track and ID consistent with commander's priorities – increased confidence in the ground and maritime picture
- ID of significant military entities (reduced fratricide, higher certainty about the target engaged) and fewer false recognition and Timely sensor information shared with combat systems
- Smart management of tactical sensors



## Challenges

- Reducing uncertainty of information
- Coordinating sensor management to be responsive to observation constraints, issues of interest and entities
- Preservation of data pedigree for greater confidence and to support drill-down information



## Specific Program Goals



- Automated integration of disparate sources of information
  - Issues to address
    - Minimizing uncertainty of information; Maximizing its expected value
    - Ability to uncover trends in activity, links among objects, and hidden models of behavior/activity
    - Preservation of data integrity
  - Candidate projects include
    - Allocate sensors and integrate the information they provide
    - Data mining to support searching vast amounts of data for activity of interest, including intelligent agents
    - Data schemas for data fusion and data mining
    - Techniques to access additional, original information on an as-needed basis
      - Preservation of data integrity
      - Maintenance of pedigrees
      - Ability to link one form to information to derived products

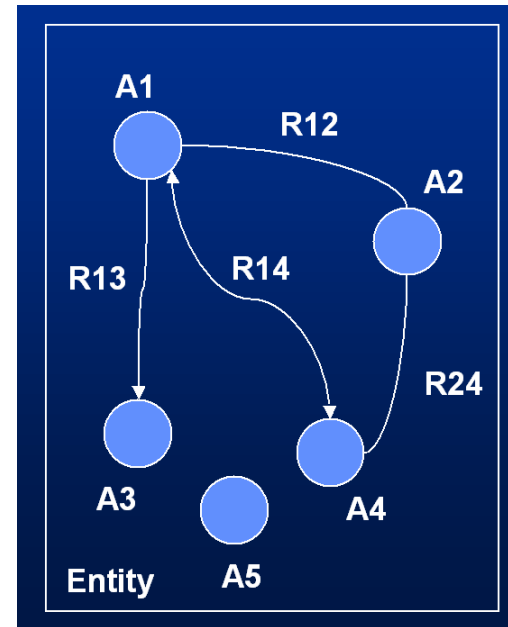
# Scalable Fusion of Disparate Information Sources

## Product / Deliverable

- New representations of L1 data to support the distributed fusion of disparate sources of information
- Sensor management algorithms to optimally manage bandwidth & sensor cuing
- Extensible method for representing the state of a system
- Hardware demonstration of the algorithms and techniques

## Naval Relevance

- More complete operational picture based on fusion of sensor data
- Improve engagement outcomes:
  - Reduce blue-on-blue fratricide
  - Higher certainty about the target being engaged



## Challenges

- A framework that can dynamically & automatically incorporate new sensor attributes
- Volume raw data makes distribution infeasible
  - Must minimize uncertainty
  - Information must be expressed using data schemas that encode both attribute values and pedigrees.
  - Underlying data fusion processing must maintain a high degree of integrity in the face of various mitigating factors



## Specific Program Goals



- Level 2 / Level 3 Information Fusion
  - Level 2: ***Situation awareness*** – Recognize objects/entities in the regions of interest, as well as recognize activities of these objects, and infer their relationships
  - Level 3: ***Threat assessment*** -- Infer intent of objects/entities, or groups of objects, in the regions of interest
  - Issues to Address
    - Understanding technical relationships and future developments
  - Candidate Projects Include
    - Abductive engines – capability to confirm/discount hypotheses asserted by humans or machines to reveal activities or trends that have not been previously recognized/related to
    - Control frameworks and tools – aggregate and manage hypotheses about battlespace activities/behaviors with consideration for feasibility/likelihood of relationships and computational constraints
    - Inference Engines – Forming hypotheses based on reasoning about knowledge and information sources having representations consistent with the variety of military sources/sensors and associated processes

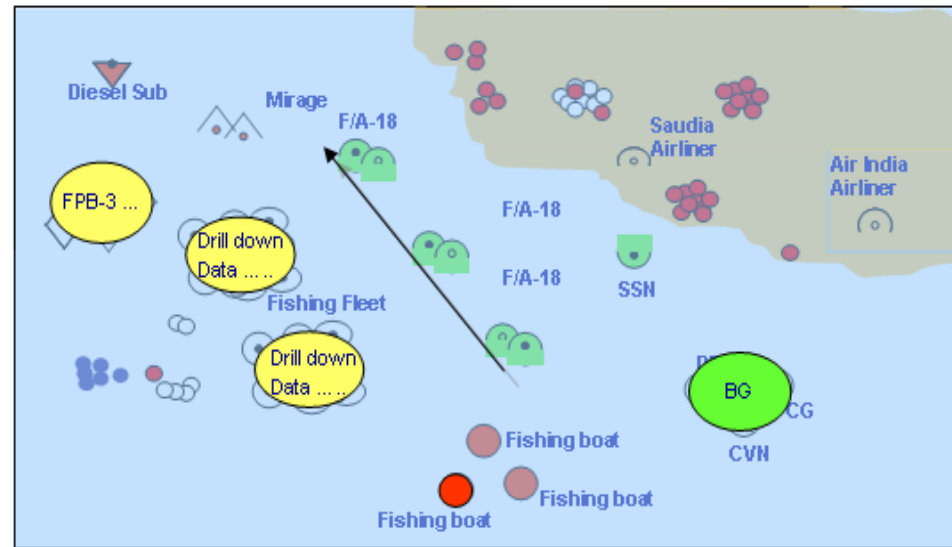


## Product / Deliverable

- Semi-supervised detection algorithms for multi-sensor imagery, video, and HUMINT
- Data fusion algorithms to detect potential targets within transactional data (communications, financial, shipping data, etc.) using graph and pattern matching on raw data
- Automated situation understanding of normal object operating patterns

## Naval Relevance

- Automated capability to recognize anomalies that indicate hostile intent in the maritime / littoral domain.
- Improved decision support through automated production of decision-quality information
- Reduces manpower requirements



## Issues

- Identification of techniques for representation of knowledge uncertainty
- Developing capability to form hypotheses based on the information from a variety of military sources/sensors and associated processors
- Identifying techniques for aggregating and managing hypotheses about battlespace activities/behaviors with consideration for computational constraints and feasibility/likelihood of relationships



# EC-1C: Combat ID Information Management of Coordinated Electronic Surveillance



- **Two Goals:**

- **Actionable Information**

Integration of fused cryptologic & intel information needed to make and execute decisions

- **Improved Maritime COTP**

Automates gathering and analyzing all available info, and managing resources.

**Products:**

1. Automated integration of multi-INT surveillance & reconnaissance of red, white, and blue force locations for Combat ID by providing software integrated into Navy and Marine Corps Command Control & Combat Systems
2. Algorithms that enable Navy Command Control & Combat Systems to employ organic sensors in conjunction with fused intel products
3. Software to provide dynamic updates to maintain currency of locations and ID.
4. Tailorable HCI in context of warfighter mission needs

**Metrics:**

1. Order of magnitude fewer false recognition and ID of significant military entities consistent with sensor capabilities. Automate speed of processing of multi-int information: two orders of magnitude faster production of information for analyst to use relative to manual, single-INT. Order of magnitude fewer false detection and false recognition. At least Digital Terrain Elevation Data (DTED) level 2 geolocation quality depending on combination of sensors Warfighter & intel views 90% consistent with mission goals.
2. Sensor resources allocated effectively to maintain Track and ID of objects consistent with the precision and completeness required as battlespace phases evolve. Latency of less than ten minutes for battlespace information updates.
3. Faster planning of assets allocated to fill ISR coverage gaps, 100X faster.

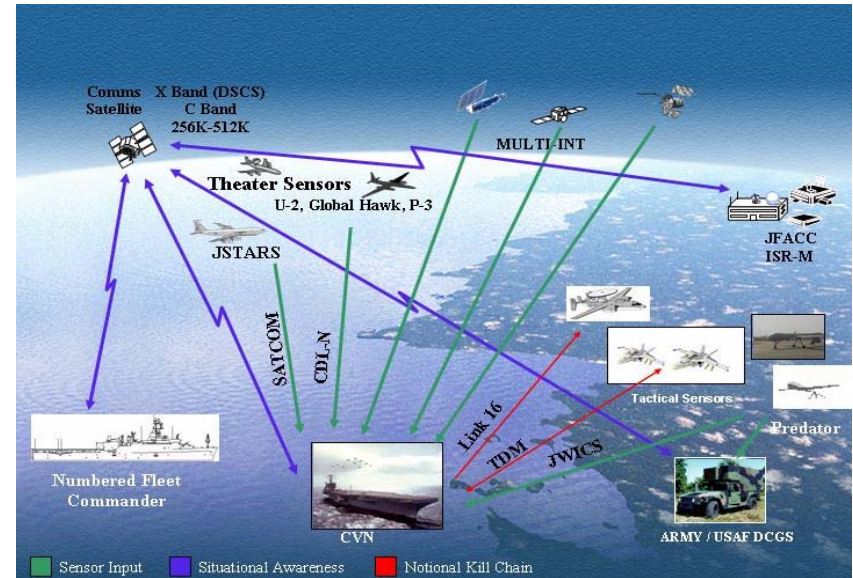


# Actionable Information Produced from Multiple Intelligence Sources in a Global Information Grid Enterprise Service Environment



## Product Description

Automated integration of multi-INT surveillance & reconnaissance of red, white, and blue force locations for Combat ID by providing software integrated into Navy and Marine Corps Command Control & Combat Systems



## Sea Trial and Transitions

- Sea Trials
  - FY07: simulation based experiment to confirm exit criteria & metrics
  - FY08 & 09: Limited Objective Experimentation
  - FY-10 Trident Warrior
- Transition: PEO C4I & Space (SSEE), MARCORPSYSCOM PM (I) & DRPM DCGS-N

## Warfighting Payoff

- Surface and undersea forces have greater freedom of action
  - Order of magnitude fewer false recognition and ID of significant military entities consistent with sensor capabilities
- Commander has increased confidence in the ground and maritime picture





# Improved Maritime COTP in the Global Information Grid Enterprise Services Environment



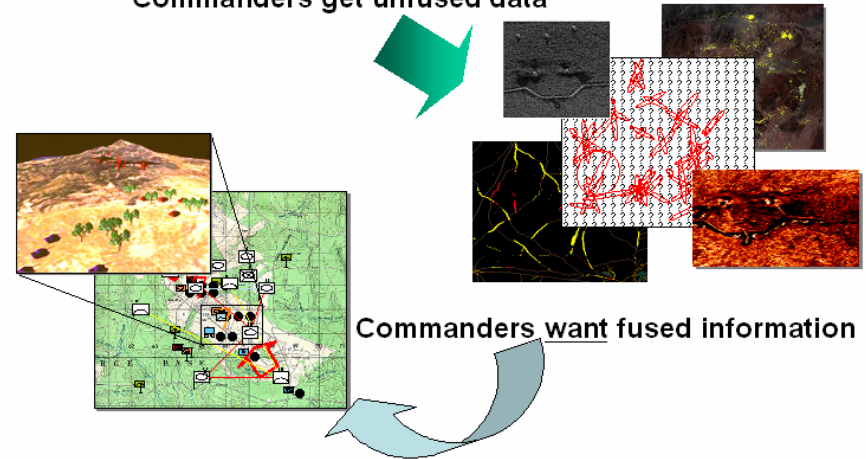
## Product Description

Algorithms that enable Navy Command Control & Combat Systems to employ organic sensors in conjunction with fused intelligence products

- Provides fusion-based knowledge about sea surface, subsurface, and maritime air and ground entities
- Level one fusion of organic tactical sensors (e.g, radar, UGS, & ESM) with intelligence information
- Coordinates management of organic tactical sensors with intelligence product coverage

## Application of Fusion Technology

Commanders get unfused data



## Sea Trial and Objective Transitions

- Sea Trials
  - FY 08 Sea Trial LTE
  - FY 09 Sea Trial Event
- FY 10 transition to:
  - PEO C4I & Space (GCCS-M)
  - PEO IWS (Open Architecture)

## Warfighting Payoff

- More effective use of tactical sensors
  - Tactical sensor resources allocated effectively to avoid redundancy, fill voids, and complement INTEL coverage
  - Maintain Track & ID consistent with Commander's priorities
- Improve engagement outcomes:
  - Reduce blue-on-blue fratricide
  - Higher certainty about the target being engaged
  - Reduce exposure of friendly forces to hostile action



# EC1D: Combat ID in the Maritime Domain to Reveal Contact Intent



- **GOAL:** Develop machine reasoning capability to aggregate COTP supplied information With contextual information such as: weather, activity patterns, open source records, market demands, hostile objectives, etc.
  - To establish relationships among such entities as sea surface, subsurface, and ground-borne objects, events, and the situation
  - In order to understand situations (e.g. routine activity/behavior, adversary capabilities and dependencies, own force vulnerabilities), and
  - Anticipate threats (e.g. adversary options, enabling events/activities)
- **Operational Capability Gap**
  - Monitoring of dynamic maritime / littoral situation, and estimation of hostile intent is a manual function, involving a large number of variables (beyond current track state), requiring multi-disciplinary analytic support and considerable time, not generally available.
  - Reasoning about diverse information, (e.g. tracks, traffic patterns, cargos, crews, affiliations, weather, terrain) cannot be performed in a complete or timely manner.
- **New Operational Capability: Near real-time support to operating forces on the edge**
  - Automated capability to establish routine behaviors & dependencies and recognize anomalies that indicate hostile intent in the maritime / littoral domain.
  - Automated contextual reasoning about large amounts of diverse information in order to relieve manual workload and provide complete, timely coverage in support of human decision makers.



***Naval forces (surface, subsurface, air, ground) operating in the maritime domain.***

**Start Date: FY07**



# Why Now?



- Several promising technologies are now available
  - Blackboard methods/tools are now more robust including commercially available generic blackboards
    - Enables both *relational* structure to maintain alternate hypotheses and *control* structure to satisfy decision maker and computational constraints
    - Leverages new capabilities in agent based computing, semantic annotation, and knowledge representation
  - Bayes Net technology has advanced to allow practical approximation algorithms for Bayesian reasoning
    - Trades-off quality and complexity allowing potential “design-to-time” control
    - Structure of Bayes nets supports control reasoning for “anytime” algorithm solutions
  - Recent DARPA work in knowledge bases (e.g. RKF) has addressed knowledge acquisition and authoring techniques
    - Enables extension of existing knowledge bases.
    - Allows SMEs to author qualitative probabilistic knowledge
  - Techniques for visualization of complex information have advanced to aid humans in hypothesis management and solution visibility.
    - Hybrid continuous / discrete probabilistic prediction for intelligent simulation of threat activity under real physical constraints (e.g. terrain, weather, lightning)



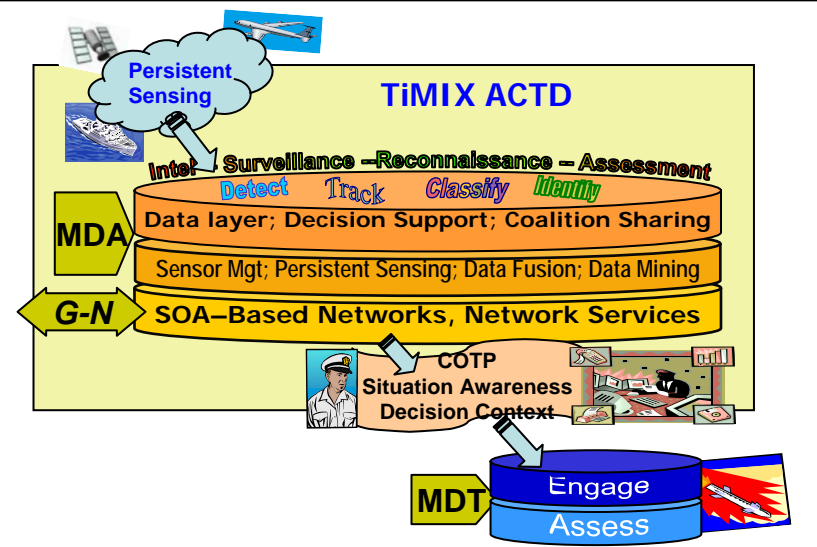
# TiMIX ACTD

## Timely Maritime Information and eXchange

FY07 ACTD  
Candidate  
**FORCEnet**  
engineering  
conference

**Problem:** Inability to maintain surveillance of all maritime regions with sufficient fidelity to characterize all significant vessel/vehicular traffic and to filter suspicious behavior or potential threats for further prosecution.

**Objective:** Deliver new technologies and processes to perform global monitoring of maritime activity across Joint / Coalition Force Maritime Component Commanders (J/CFMCC) to develop a Global Maritime Domain Awareness (MDA) that supports Regional COCOM Maritime missions.



### Participants:

OM: NORTHCOM, PACOM, EUCOM  
XM: PEO C4I ; DRPM DCGS-N  
TM: Office of Naval Research  
Others: JFCOM, USAF, CENTCOM

### Schedule:

FY07-08 – Concept Exploration, Integration of processing techniques in Service Oriented Architecture, Performance Testing  
FY08-10 – Technical Feasibility Testing, Sea Trial, Military Utility Demonstrations  
FY11-12 – Extended User Evaluation, Sustainment

### Benefits:

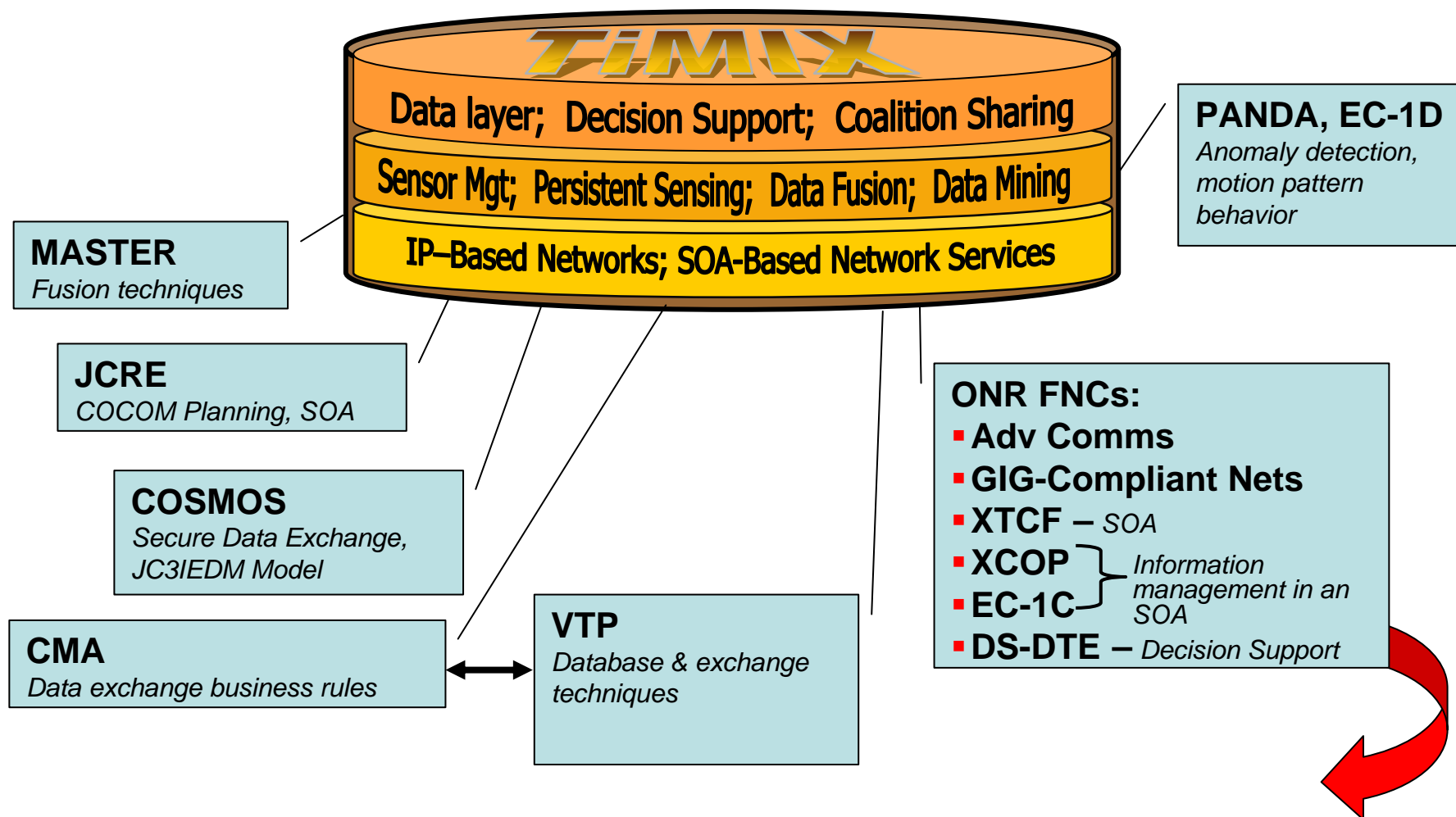
- Improved Global Situational Awareness
- Improved automated processing and analysis
- Automated all source data fusion, data mining, sensor management, decision aids
- More complete and accurate coverage with reduced manpower and improved speed

### POC:

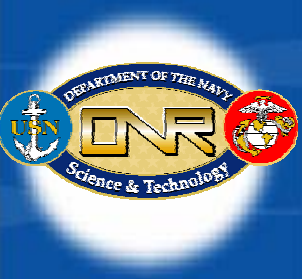
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# TiMIX Technology Leveraging



Leverages FY04/05/06 S&T and Sea Trial Experimentation Investment



# Back Up Slides





# Timely Maritime Information and Exchange



- **Why?** Deliver new technologies and processes to perform global monitoring of maritime activity across Joint / Coalition Force Maritime Component Commanders (J/CFMCC) in support of Regional COCOM Maritime Domain Awareness (MDA) objectives.

Responsive to Draft FFC “Globally Netted J/CFMCC CONOP”

- **What?** Deliver an SOA-based capability to automate sensor planning, and all-source data processing, analysis, and adaptable decision support to validate CONOPS and develop TTPs; includes coordinated allocation of sensors for persistent sensing, data fusion, data mining, and decision aids.
- **Who?**

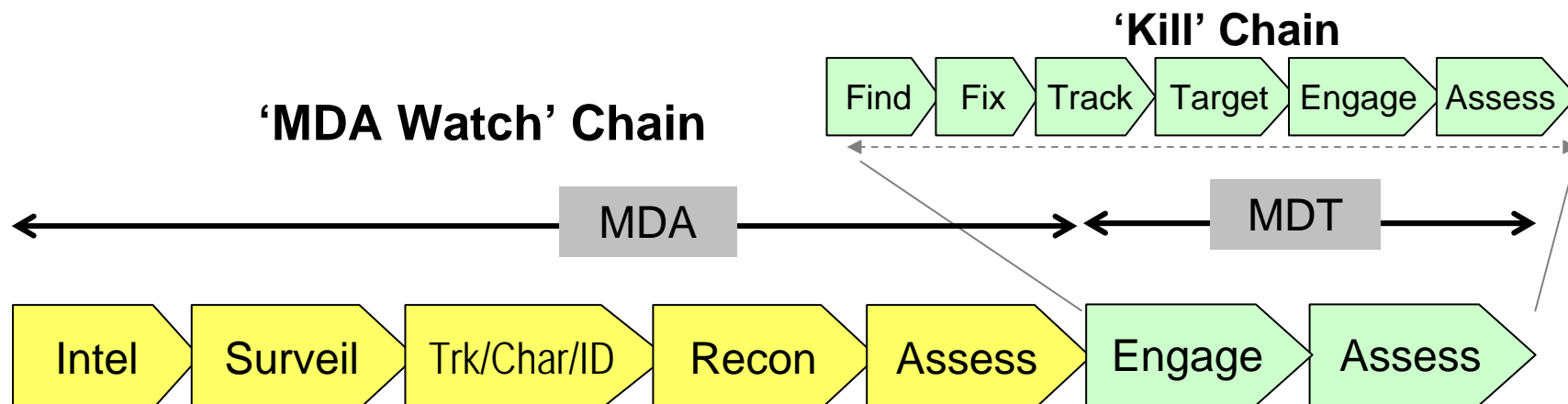
Operational Manager	NORTHCOM	PACOM	EUCOM	ONI, NCIS	OPNAV
Fleet	FFC C2F	CPF C3F	CNE C6F		CNNWC
Tactical	TBD	FSF X-Craft	TBD		
Transition Manager	PEO C4I&S	DRPM DCGS-N			
Program	JC2	DCGS			
Technical Manager	ONR				

- **When?** FY07 planning start; complete development engineering and performance testing in FY10; Perform military utility assessment and operational sustainment through FY12



# TiMIX ACTD addresses Global MDA

*Supports GWOT "defense in depth" Homeland Defense (HLD) missions, Stability Operations, and transition to Major Combat Operations (MCO)*



***TiMIX will focus on C2/ISR capability to provide:***

**Global (large area) monitoring of maritime activity**

***Operational:***

- Monitor traffic details, understand behavior patterns – establish normalcy
- Recognize anomalous behavior
- Access / Share relevant traffic and contextual information with low latency
- **Hand-off to tactical forces for Maritime Dynamic Targeting**

***System / Technical:***

- Service Oriented Architecture with persistent sensing, robust information processing and dissemination
- Interface with legacy feeds, processes, and users as needed
- Growth or composable capability to meet evolving future demands or regional needs





# Delivered Capability



- **Global netted C/JFMCC for Improved Maritime Domain Situational Awareness**
  - Accelerates PEO C4I schedule for delivering fully netted JFMCC capability approximately 4 years ahead of plan
  - Supports Regional COCOMS in executing MDA responsibilities
  - Supports HLD/HLS needs with timely and relevant global awareness
  - ✓ **Residual: SOA hardware and software, integrated with legacy systems/feeds**
- **Automated planning, processing and analysis capability**
  - All source data fusion, data mining and decision aids
  - Coordinated allocation of resources and deployments
  - ✓ **Residual: Standards based algorithms and tools for processing large data sets**
- **Means to gather, analyze, share relevant Maritime Domain information and support rapid, adaptable cross-theater decision making**
  - Reduced manpower and faster speed of command
  - More complete, and accurate coverage
  - Shared Awareness
  - Better decision making
  - ✓ **Residual: Structured implementation of data layer and decision support tools for information sharing and user collaboration**

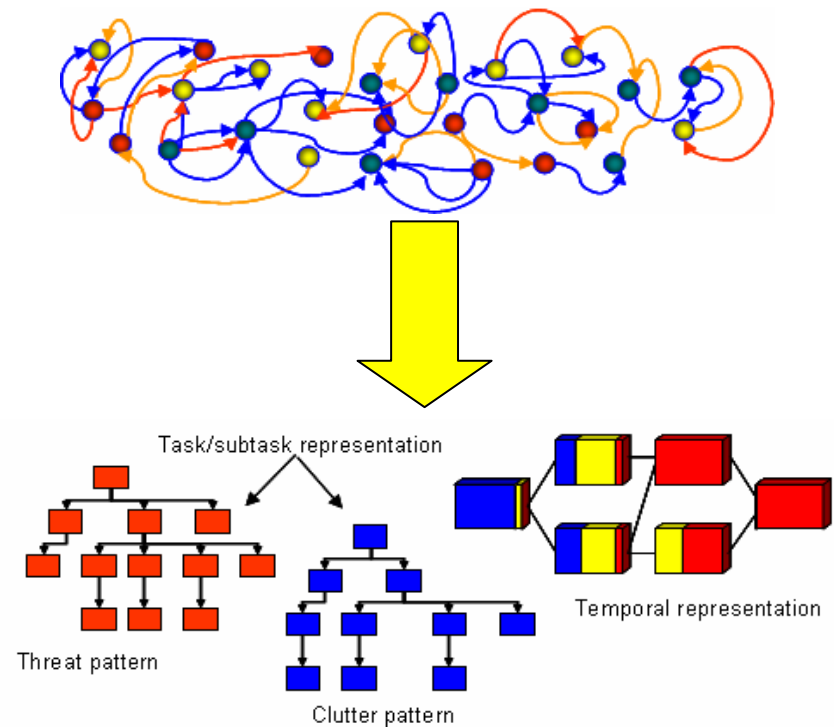
**This ACTD becomes the prototype for gathering metrics and decisions needed to develop JC2**

## Product / Deliverable

- Data fusion algorithms to detect potential targets from transactional data/noise (communications, financial, shipping data, etc.) using link analysis tools to assess large amounts of raw data

## Naval Relevance

- Detecting, classifying, and tracking potential hostile activities in massive amounts of transactional noise
  - Important in GWOT
  - Complements MDA ship tracking
- Ability to detect threat events and organizations prior to attack
  - Supports precision strike (Sea Strike)
  - Enhanced common tactical picture
  - Detection of shipping anomalies for Naval Intelligence
  - Commander has increased confidence in intelligence information



## Issues

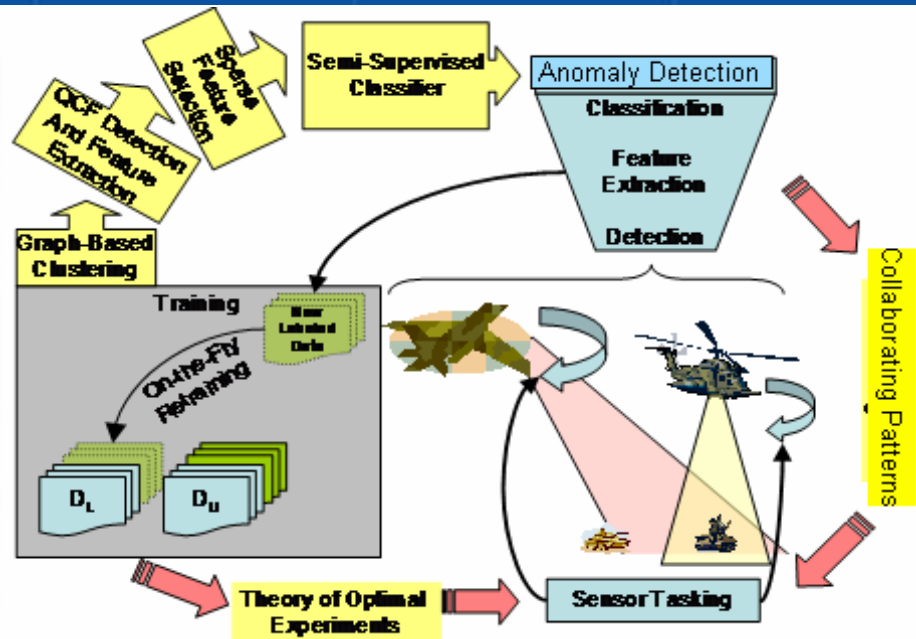
- Transactional noise is not well understood
- Current link analysis technology and methods are not scalable to today's massive amounts of data

## Product / Deliverable

- Semi-supervised detection algorithms for multi-sensor imagery, video and HUMINT
- The algorithms will be integrated into software that will be deployed in prototype systems (Lockheed Martin)
- Prototype algorithms to be tested in Navy-relevant environments (DCGS-N Advanced Concept Testbed)

## Naval Relevance

- Improved urban and base security through ability to detect anomalous behavior
- decisions/control using multi-sensor imagery, video and intelligence, consistent with FORCEnet objectives
- Reduced shipboard workload: system designed to ease the burden of the military analyst



## Issues

- Integrating multiple sensors with HUMINT
- Ability to integrate labeled and unlabeled data
- Ability to develop techniques that pre-process data and help guide sensors (self-deploying sensors)